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(54) **FORMATION TESTER WITH LOW FLOWLINE VOLUME AND METHOD OF USE THEREOF**

(75) Inventors: **Anthony R. H. Goodwin**, Sugar Land, TX (US); **Julian J. Pop**, Houston, TX (US); **Stephane Briquet**, Houston, TX (US); **Ricardo Vasques**, Bailly (FR); **Alexander Zazovsky**, Houston, TX (US)

(73) Assignee: **Schlumberger Technology Corporation**, Sugar Land, TX (US)

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E21B 49/10	(2006.01)
E21B 27/00	(2006.01)

(52) **U.S. Cl.** **166/264**; 166/165

(58) **Field of Classification Search** 166/264, 166/165; 175/59, 308; 73/152.23–152.26
See application file for complete search history.

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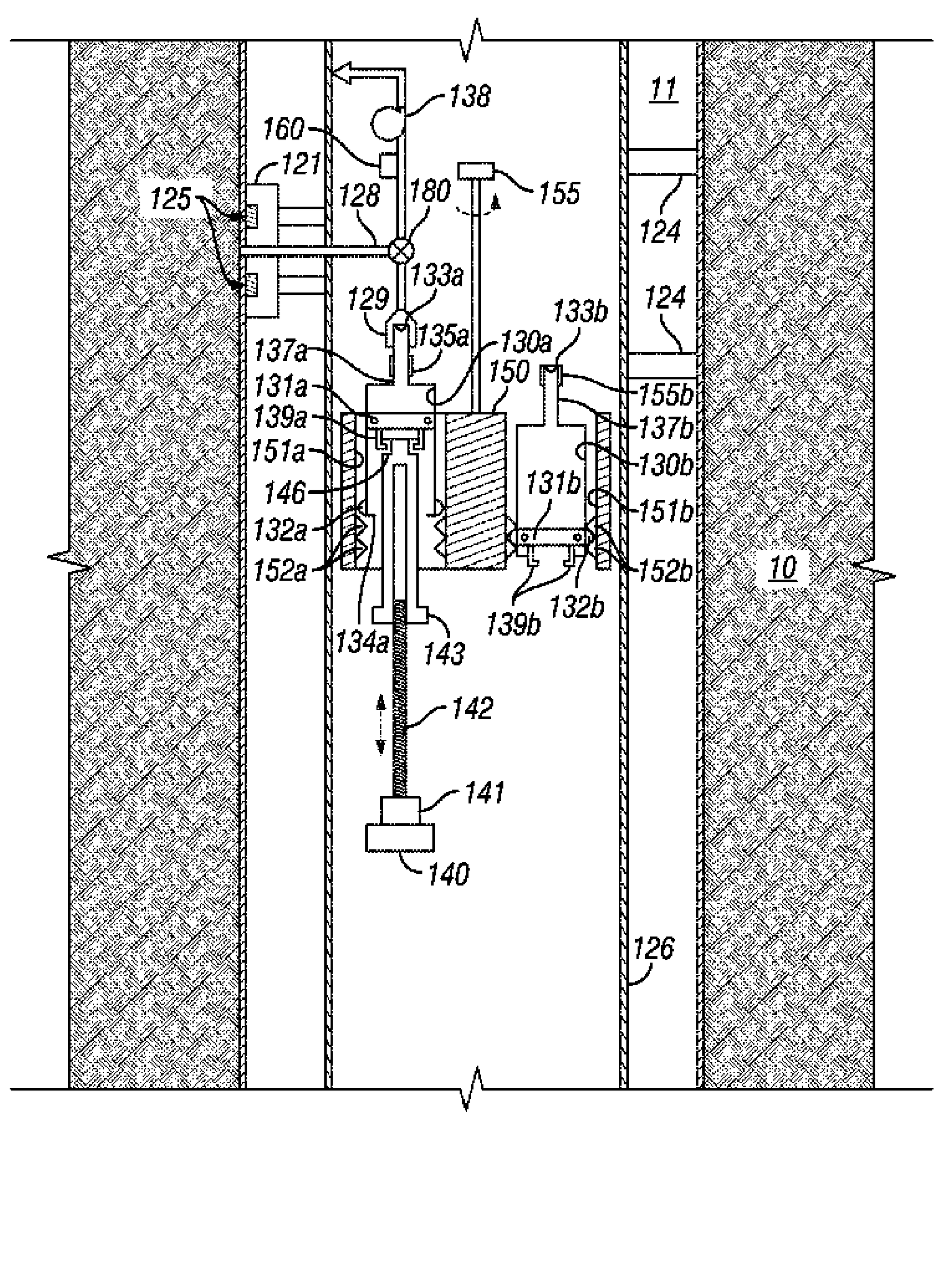
Primary Examiner — Cathleen Hutchins
(74) *Attorney, Agent, or Firm* — David J Smith

(57) **ABSTRACT**

A downhole tool for use in a well may comprise a vessel having a piston or a valve disposed therein and defining first and second volumes wherein the first volume is configured to receive formation fluid from an inlet port, and an actuator configured to extract formation fluid, the actuator being fluidly isolated from a fluid flow path extending between the inlet port and the first volume. The downhole tool may also comprise a flow-line configured to deliver formation fluid to the vessel, and an actuator configured to register an end of the flow-line with the inlet of the vessel.

21 Claims, 9 Drawing Sheets



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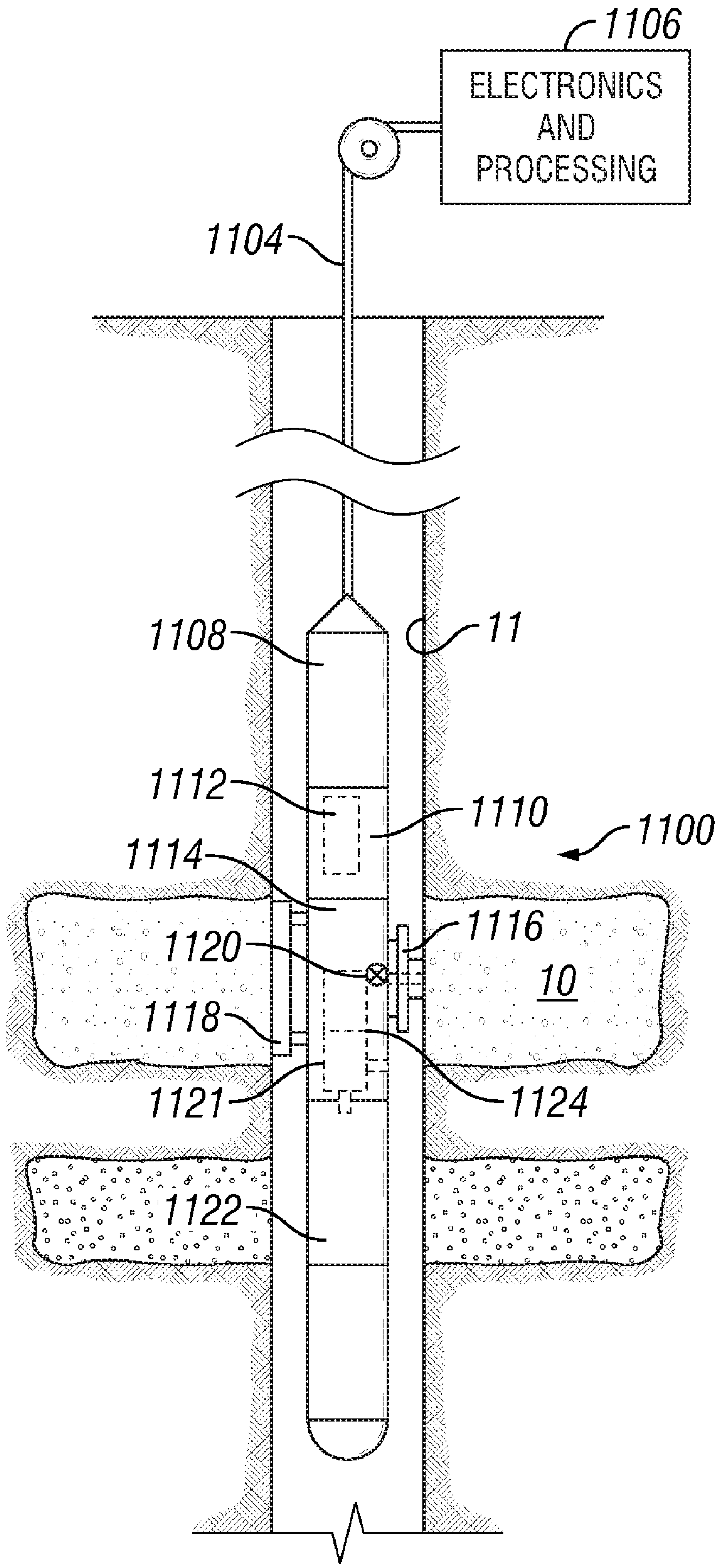
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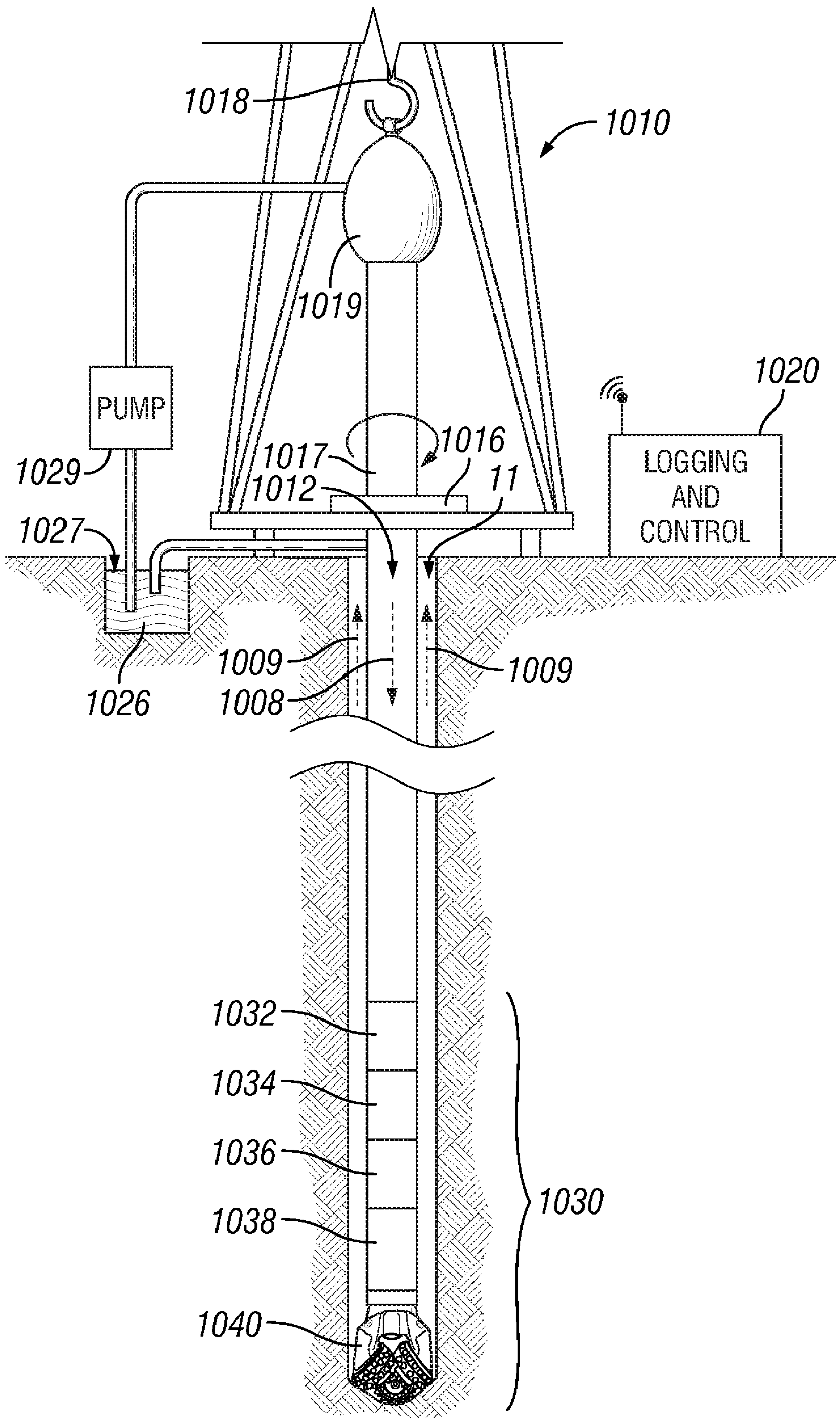
ELECTRONICS AND PROCESSING
1104
1108
11
1112
1110
1100
1114
1116
1120
10
1118
1121
1124
1122

FIG. 1


1018
1010
1019
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1020
LOGGING AND CONTROL
1017
1016
1012
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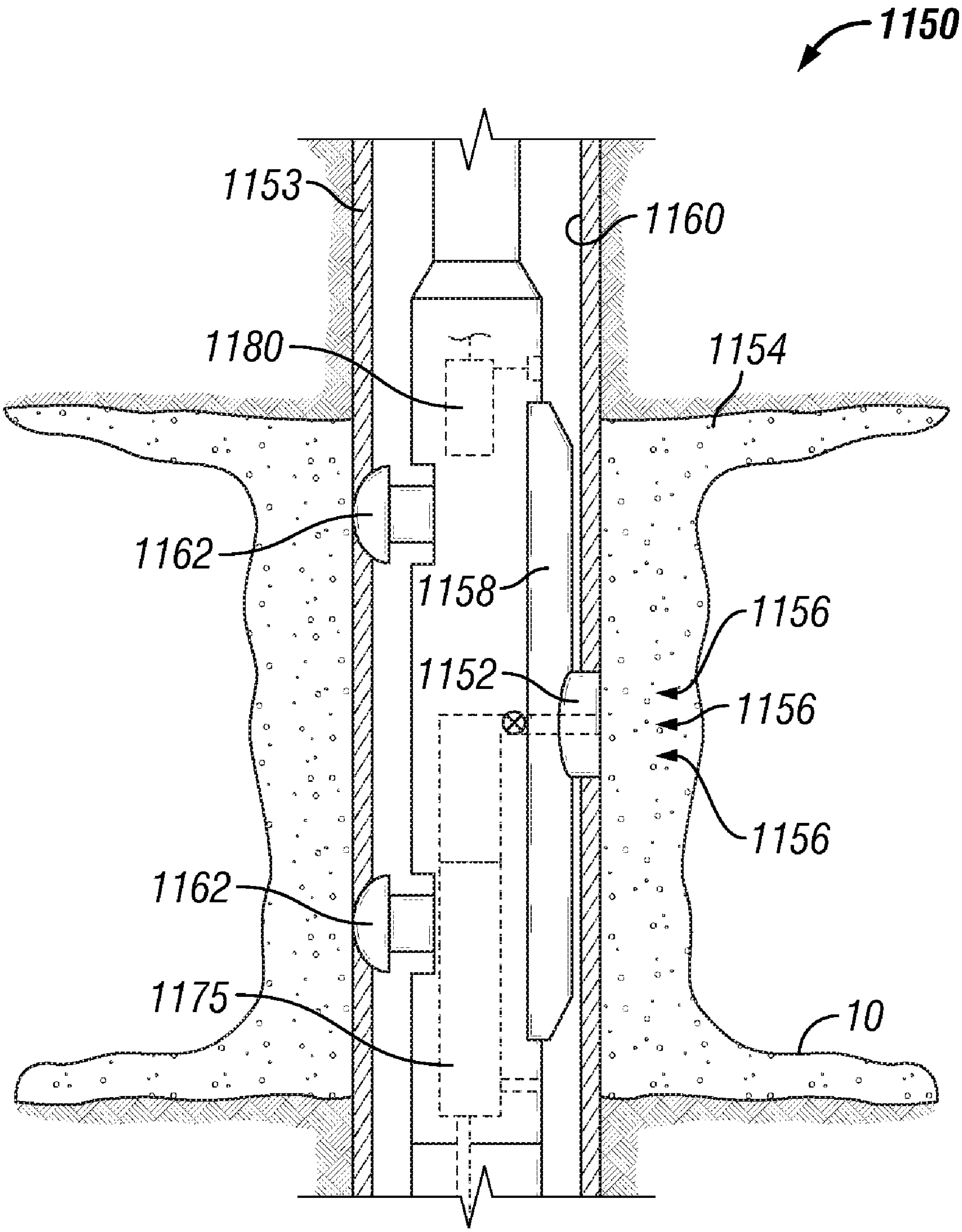
1027
1026
1009
1008
1009
1032
1034
1036
1038
1030
1040

FIG. 2A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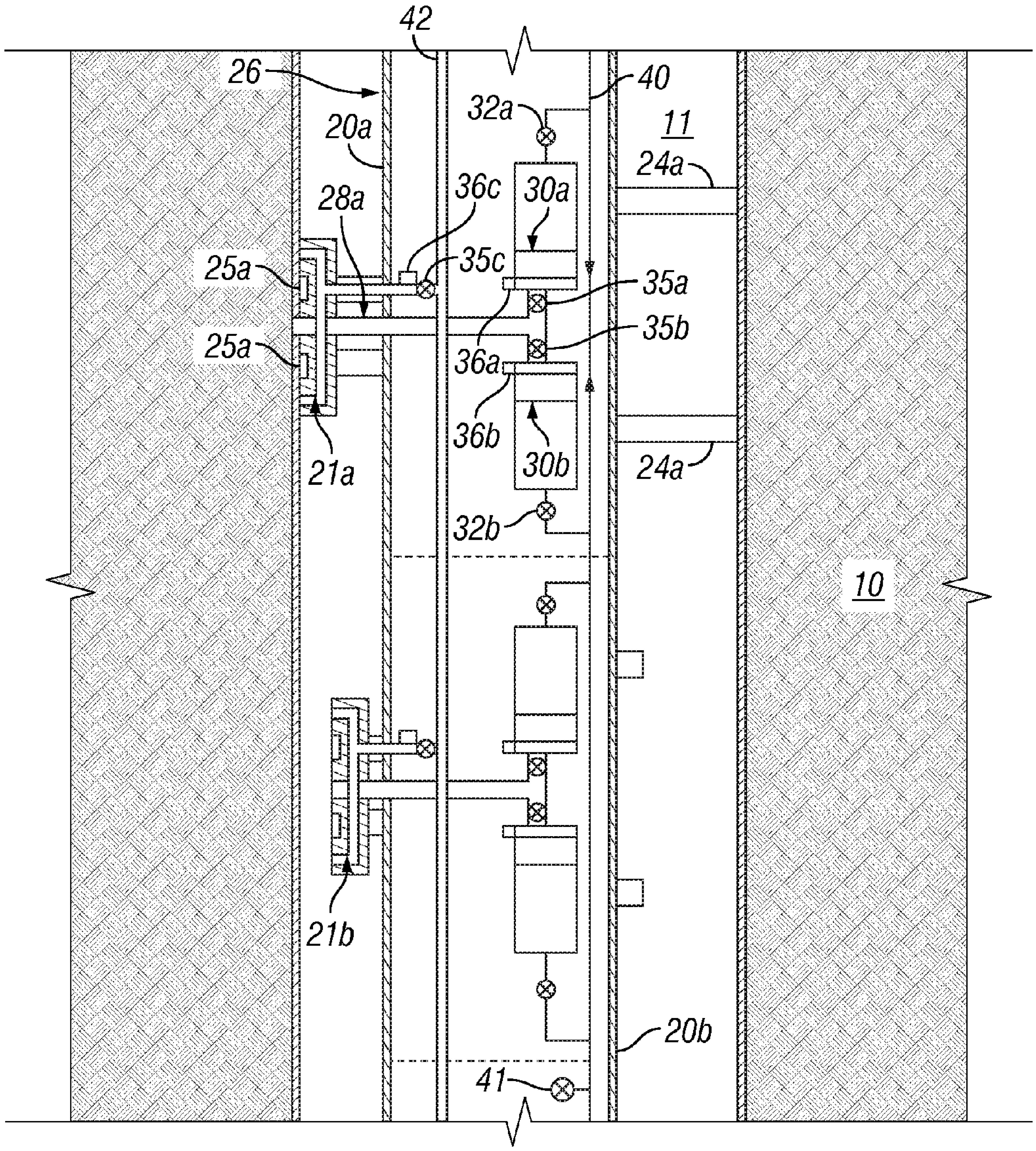
1153
1160
1180
1154
1162
1158
1156
1152
1156
1156
1162
1175
10

FIG. 2B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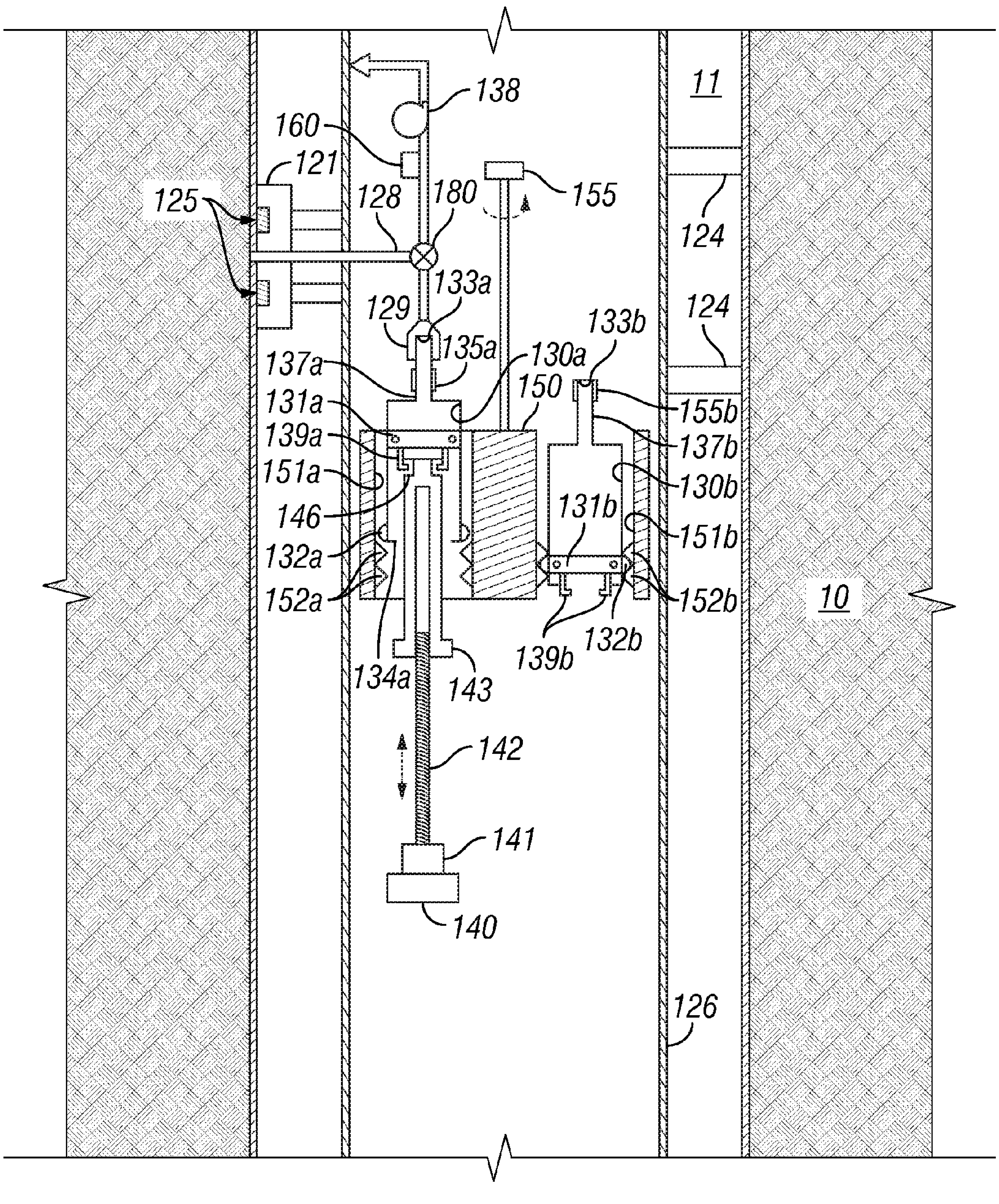
26
20a
28a
36c
30a
35c
35a
35b
36a
36b
30b
25a
25a
21a
32a
32b
40
11
24a
24a
10
21b
20b
41

FIG. 3



138
11
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121
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125
128
180
124
133a
124
129
133b
135a
137a
130a
150
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131a
137b
139a
130b
151a
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152b
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141
140
126

FIG. 4A

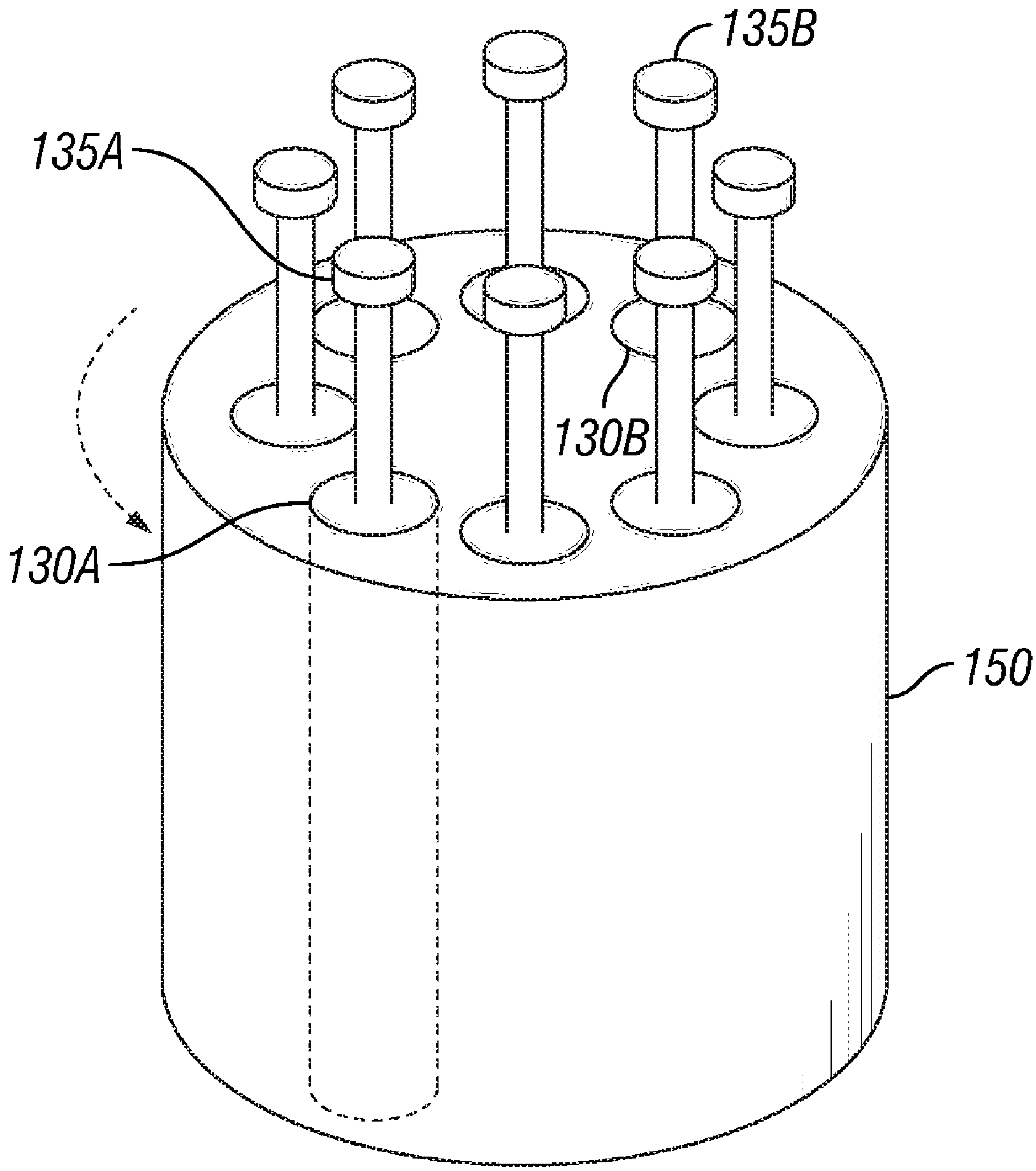
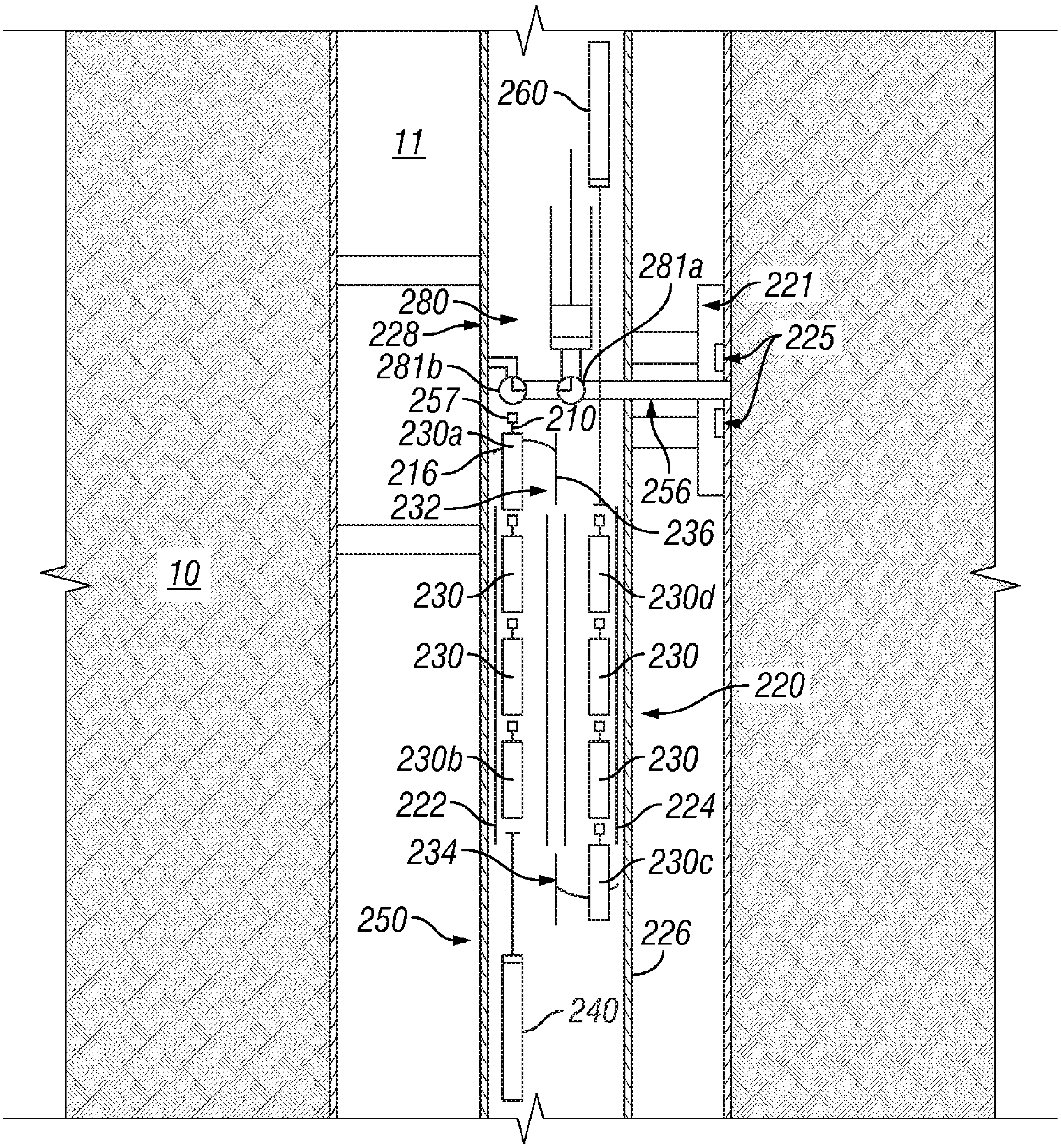


FIG. 4B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281b
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230d
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230b
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234
230c
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226
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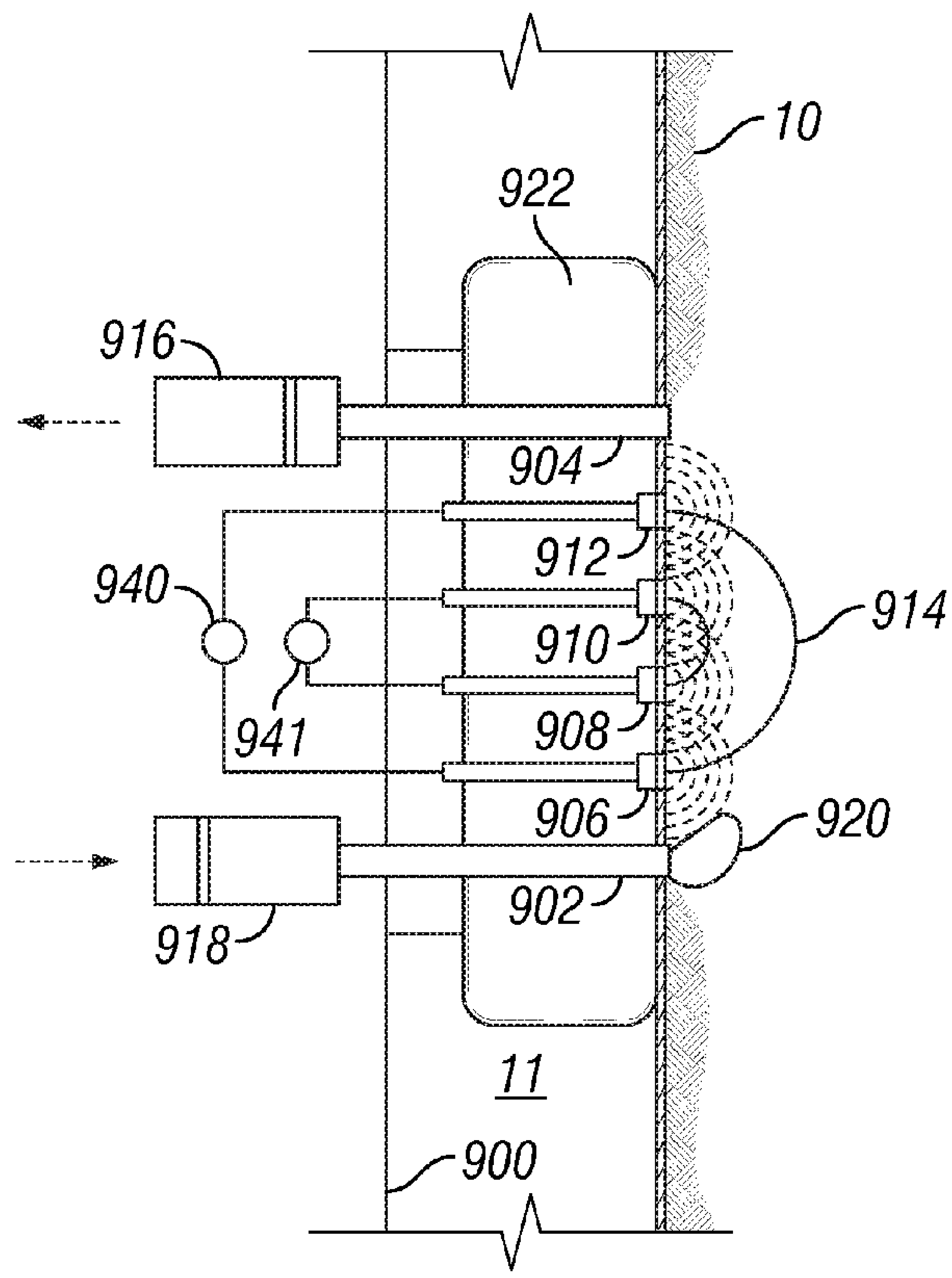
FIG. 5



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916
904
912
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910
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902
11
900

FIG. 6

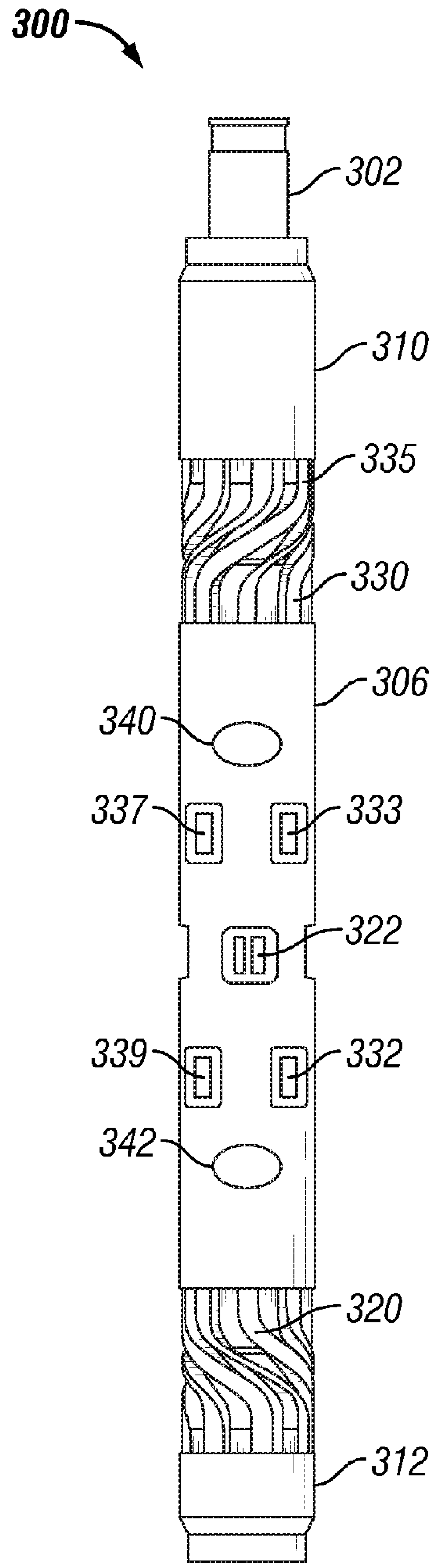

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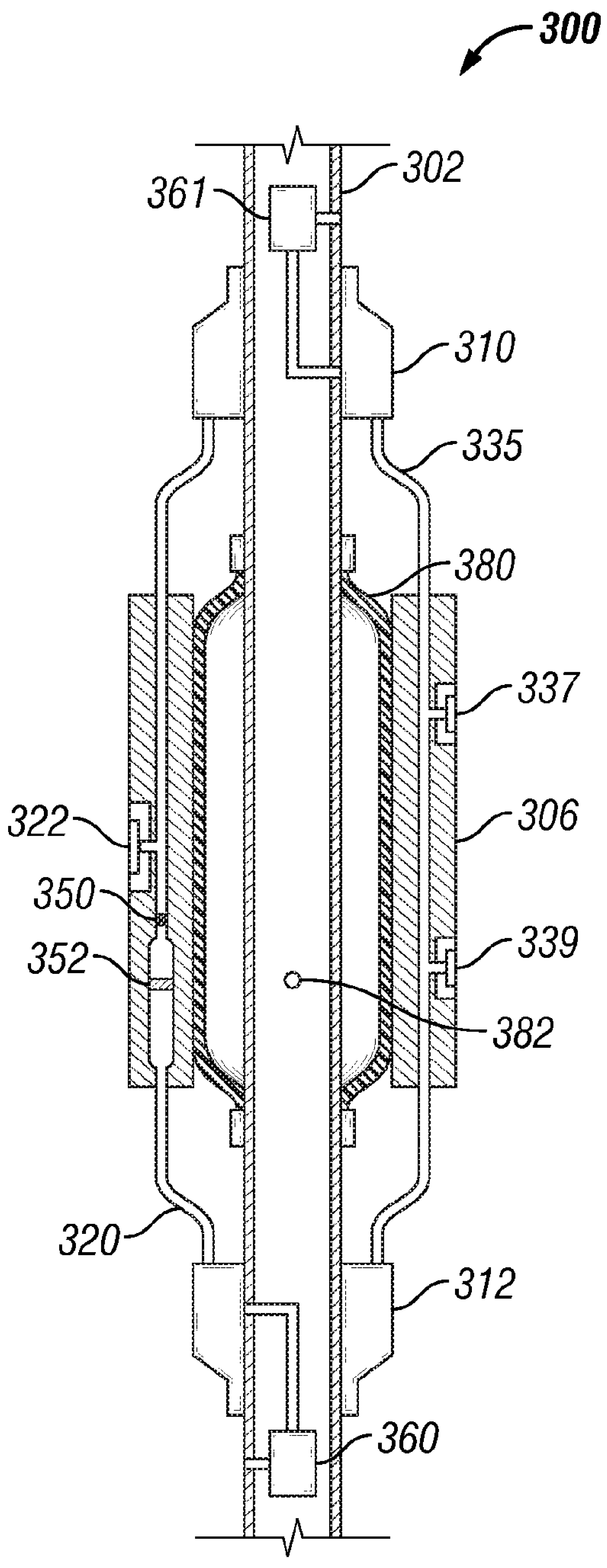
FIG. 7A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380
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306
322
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352
339
382
320
312
360

FIG. 7B

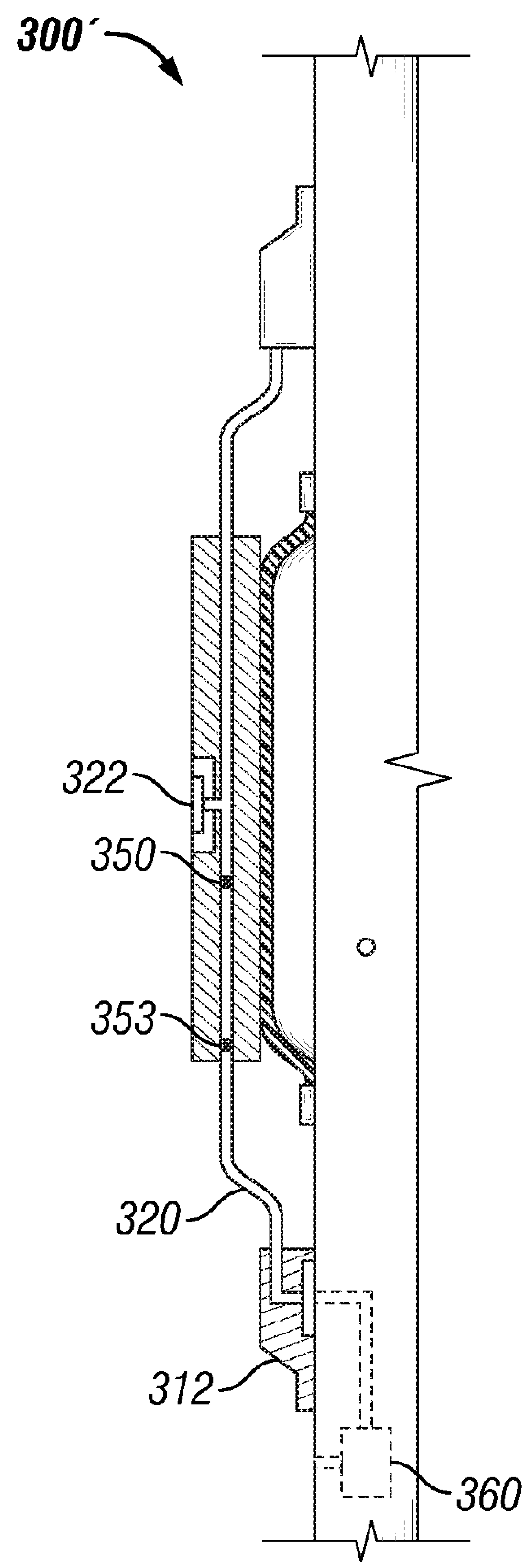
300′
322
350
353
320
312
360

FIG. 7C

FORMATION TESTER WITH LOW FLOWLINE VOLUME AND METHOD OF USE THEREOF

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application No. 61/022,996, entitled "FORMATION TESTER WITH LOW FLOWLINE VOLUME," filed Jan. 23, 2008, the disclosure of which is hereby incorporated herein by reference. This application is also related to U.S. patent application Ser. No. 12/368,738, filed on Feb. 10, 2009, and titled "Single Packer System for Use in Heavy Oil Environments."

BACKGROUND OF THE DISCLOSURE

Formation testers and related sampling procedures for acquiring conventional oil samples from underground formations have been described in U.S. Pat. Nos. 4,860,581 and 4,936,139, amongst others. Example sampling procedures may include the use of sampling probes of various geometries and/or packer assemblies to fluidly connect the formation tester to the formation and extract fluid from the formation. Within the formation tester, flow-lines usually convey the fluid extracted from the formation through fluid analyzers, and eventually to one or more of a plurality of sample storage vessels that may be located several meters away from the point of entry (e.g. a sampling port) of the formation fluid into the formation tester. Typically, the diameter of the flow-lines may be on the order of 10 mm. Thus, the volume of an average 10 m flow-line between the point of entry of the formation fluid and a sample storage vessel may be approximately 800 cm^3.

During sampling operations, the fluid initially present in the flow-lines is pumped out of the testing tool into the wellbore, and is progressively replaced by formation fluid extracted from the formation. In the cases when conventional oil (i.e. oil relatively mobile in the formation) is sampled, the flow-line volume is small compared with the volume of fluid that is usually extracted from the formation during a sampling operation. Indeed, it is not unusual to pump a volume on the order of 10,000 cm^3 during the sampling operation, which is more than 10 times the flow-line volume mentioned above. Thus, the flow-line volume in the formation tester has usually a negligible impact on the sampling procedure. However, in the cases when heavy oil or bitumen, (i.e. hydrocarbon that may not be mobile at reservoir conditions) is sampled, it may be difficult to mobilize and extract a volume of formation fluid corresponding to the flow-line volume in addition to the volume of the fluid to be captured in a vessel of the formation tester.

For example, mobilizing the heavy oil and bitumen may be achieved by increasing the temperature of the formation near a sampling port of the formation tester. It should be appreciated that the thermal diffusivity of formations is many orders of magnitude lower than the thermal diffusivity of, for example, metals. Thus, the time required for the thermal wave to penetrate the formation sufficiently far into the reservoir to permit the temperature of an adequate volume of fluid to be increased and/or an adequate volume of fluid to be mobilized may be long. In particular, when using a resistive heating element positioned on the bore-hole wall, mobilizing about 1,000 cm^3 of fluid close to a sampling probe while minimizing the thermal degradation of the hydrocarbon may require the formation to be heated for about two days. If mobilizing an additional volume of 1,000 cm^3 is desired, then on the order of one more day may be required.

BRIEF DESCRIPTION OF THE DRAWINGS

The present disclosure is best understood from the following detailed description when read with the accompanying figures. It is emphasized that, in accordance with the standard practice in the industry, various features are not drawn to scale. In fact, the dimensions of the various features may be arbitrarily increased or reduced for clarity of discussion.

FIG. **1** is a schematic view of an apparatus according to one or more aspects of the disclosure.

FIG. **2**A is a schematic view of another apparatus according to one or more aspects of the disclosure.

FIG. **2**B is a schematic view of the sampling apparatus shown in FIG. **2**A.

FIG. **3** is a schematic cross sectional view of a modular testing tool lowered in a wellbore having a low flow-line volume between a sampling port and a tree of sample storage vessels.

FIG. **4**A is a schematic cross sectional view of a testing tool lowered in a wellbore having a low flow-line volume between a sampling port and one of a plurality of sample storage vessels disposed in a revolving chambered cylinder.

FIG. **4**B is a schematic perspective view in of the revolving chambered cylinder shown in FIG. **4**A;

FIG. **5** is a schematic cross sectional view of a testing tool lowered in a wellbore having a low flow-line volume between a sampling port and one of a plurality of sample storage vessels disposed in a carousel.

FIG. **6** is a schematic cross sectional view of a packer of a testing tool according to one or more aspects of the present application.

FIG. **7**A is a schematic perspective view of another packer of a testing tool according to one or more aspects of the present application.

FIG. **7**B is a schematic sectional view of the packer shown in FIG. **7**A.

FIG. **7**C is a schematic half sectional view of another embodiment of the packer shown in FIG. **7**A.

DETAILED DESCRIPTION

It is to be understood that the following disclosure provides many different embodiments, or examples, for implementing different features of various embodiments. Specific examples of components and arrangements are described below to simplify the present disclosure. These are, of course, merely examples and are not intended to be limiting. In addition, the present disclosure may repeat reference numerals and/or letters in the various examples. This repetition is for the purpose of simplicity and clarity and does not in itself dictate a relationship between the various embodiments and/or configurations discussed. Moreover, the formation of a first feature over or on a second feature in the description that follows may include embodiments in which the first and second features are formed in direct contact, and may also include embodiments in which additional features may be formed interposing the first and second features, such that the first and second features may not be in direct contact.

Formation testers configured to obtain an aliquot of formation fluid in one or more sample vessel(s) are disclosed herein. Preferably, the location and type of sample vessel(s) conveyed by the formation testers are configured to provide a low volume of flow-line between a sampling port and the sample vessel(s) conveyed by the tool. For example, the sample vessel(s) may be disposed close to a sampling port of the tool (e.g. within one meter of a sampling probe) so that the flow-line volume between the sampling port and the sample vessel is low.

In some cases, the formation testers disclosed herein may be configured to obtain samples that are representative of a hydrocarbon substance found in the formation. In particular, the formation testers may be configured to sample formation fluid, such as heavy oils, that are not mobile at reservoir temperature, or other hydrocarbons that are effectively solid at reservoir temperature, such as bitumen. Thus, the formation testers of the present disclosure may be provided with one or more mobilizer(s) (e.g. heat sources, chemical injectors, etc) configured to reduce the formation fluid viscosity in at least a portion of the formation and thus, mobilize formation fluid to facilitate sampling. However, the formation testers disclosed herein could equally well be used in other reservoir types, such as gas-condensate reservoirs, or more generally in reservoirs where it was deemed useful to minimize the volume of extracted fluid to obtain a sample.

Turning to FIG. **1**, an example wireline tool **1100** that may be used to extract and capture one or more formation fluid sample(s) is suspended in a wellbore **11** from the lower end of a multiconductor cable **1104** that is spooled on a winch (not shown) at the Earth's surface. At the surface, the cable **1104** is communicatively coupled to an electrical control and data acquisition system **1106**. The wireline tool **1100** includes an elongated body **1108** that may comprises a telemetry module **1110** having a downhole control system **1112** communicatively coupled to the electrical control and data acquisition system **1106** and configured to control extraction of formation fluid from the formation **10**, as well as store and/or communicate data indicative of the sampling operation to the surface for subsequent analysis at the surface.

The elongated body **1108** may also includes a formation tester **1114** having a selectively extendable fluid admitting assembly **1116** and a selectively extendable tool anchoring member **1118** that are respectively arranged on opposite sides of the elongated body **1108**. The fluid admitting assembly **1116** may be configured to selectively seal off or isolate selected portions of the wall of the wellbore **11** to fluidly couple internal flow-lines in the formation tester **1114** to the adjacent formation **10**. The fluid admitting assembly **1116** may be used to draw fluid samples from the formation **10** and capture the samples into one or more vessel(s) **1121** fluidly coupled to an inlet of the fluid admitting assembly **1116**.

The vessel **1121** may include a valve **1120** through which formation fluid samples may flow. The valve **1120** may be configured to selectively capture and seal samples in the vessel **1121**. Thus, the vessel **1121** may receive and retain the formation fluid for subsequent testing at the surface or a testing facility. The vessel **1121** may include a piston **1124** slidably disposed therein, the piston defining a first volume fluid coupled to the inlet of the probe assembly **1116** and a second volume isolated from the inlet of the probe assembly **1116** by the piston **1124**. An actuator **1122** (e.g. a pump) may also be provided by the formation tester **1114** and may be configured to pull or reciprocate the piston **1124**. For example, the actuator **1122** may be configured to reduce the vessel second volume thereby extracting formation fluid from the formation **10** and receiving the formation fluid in the vessel first volume. The actuator **1122** may be fluidly isolated from a fluid flow path extending between the inlet port or the fluid admitting assembly **1116** and the first volume of the vessel **1121**. In particular, the actuator **1122** may be disposed at least in part in the second volume of the vessel **1121**.

In the illustrated example, the electrical control and data acquisition system **1106** and/or the downhole control system **1112** may be configured to control the fluid admitting assembly **1116** to draw fluid samples from the formation **10**, to control the actuator **1122** to controllably reduce the vessel second volume, and/or to close the valve **1120** for capturing the sample of the downhole fluid in the vessel **1121**. Further, the electrical control and data acquisition system **1106** and/or the downhole control system **1112** may be configured to control one or more mobilizer(s) (not shown) used to mobilize the downhole fluid in at least a portion of the formation prior to or during sampling.

FIG. **2**A illustrates a wellsite system in which the example implementations can be employed. The wellsite can be onshore or offshore. In this example system, a borehole **11** is formed in subsurface formations by rotary drilling in a manner that is well known. Some example implementations can also use directional drilling.

A drill string **1012** is suspended within the borehole **11** and has a bottom hole assembly **1030** that includes a drill bit **1040** at its lower end. The wellsite system includes a platform and derrick assembly **1010** positioned over the borehole **11**. The assembly **1010** includes a rotary table **1016**, a kelly **1017**, a hook **1018** and a rotary swivel **1019**. The drill string **1012** is rotated by the rotary table **1016**, energized by means not shown, which engages the kelly **1017** at the upper end of the drill string **1012**. The drill string **1012** is suspended from the hook **1018**, which is attached to a traveling block (also not shown), through the kelly **1017** and the rotary swivel **1019**, which permits rotation of the drill string **1012** relative to the hook **1018**. As is well known, a top drive system could alternatively be used.

In the illustrated example implementation, the wellsite system further includes drilling fluid or mud **1026** stored in a pit **1027** formed at the well site. A pump **1029** delivers the drilling fluid **1026** to the interior of the drill string **1012** via a port in the rotary swivel **1019**, causing the drilling fluid **1026** to flow downwardly through the drill string **1012** as indicated by a directional arrow **1008**. The drilling fluid **1026** exits the drill string **1012** via ports in the drill bit **1040**, and then circulates upwardly through the annulus region between the outside of the drill string **1012** and the wall of the borehole **11**, as indicated by directional arrows **1009**. In this well-known manner, the drilling fluid **1026** lubricates the drill bit **1040** and carries formation cuttings to the surface as it is returned to the pit **1027** for recirculation.

The bottom hole assembly (BHA) **1030** of the illustrated example implementation includes a logging-while-drilling (LWD) module **1032**, a measuring-while-drilling (MWD) module **1034**, a roto-steerable system and motor **1038**, and drill bit **1040**. In the illustrated example, the bottom assembly **1030** is communicatively coupled to a logging and control unit **1020**. The logging and control unit **1020** may be configured to receive data from and control the operation of the logging-while-drilling (LWD) module **1032**, the measuring-while-drilling (MWD) module **1034**, and the roto-steerable system and motor **1038**. In particular, the logging and control unit **1020** may be configured to control the trajectory of the borehole **11** based on data collected from one or more component of the BHA **1030**, as well as a reference data base (not shown) coupled to the logging and control unit **1020**. While the logging and control unit **1020** is depicted on the well site in FIG. **2**A, at least a portion of the logging and control unit **1020** may alternatively be provided at a remote location.

The LWD module **1032** is housed in a special type of drill collar, as is known in the art, and can contain one or a plurality of known types of logging tools. It will also be understood that more than one LWD and/or MWD module can be employed (e.g., as represented at **1036**). (References, throughout the following description, to a module at the position of **1032** can alternatively mean a module at the position of **1036** as well.) The LWD module **1032** includes capabilities for measuring, processing, and storing information, as well as for communicating with the MWD module **1034**. In the illustrated example implementation, the LWD module **1032** includes a sampling device (not shown).

The MWD module **1034** is also housed in a special type of drill collar, as is known in the art, and can contain one or more devices for measuring characteristics of the drill string **1012** and the drill bit **1040**. The MWD module **1034** further includes an apparatus (not shown) for generating electrical power to the downhole system. This may typically include a mud turbine generator powered by the flow of the drilling fluid **1026**, it being understood that other power and/or battery systems may be employed. In the illustrated example implementation, the MWD module **1034** includes one or more of the following types of measuring devices: a weight-on-bit measuring device, a torque measuring device, a vibration measuring device, a shock measuring device, a stick slip measuring device, a direction measuring device, and an inclination measuring device. The MWD module **1034** also includes capabilities for processing, and storing information signals from the LWD module **1032** and **1036**, as well as for communicating with the surface equipment.

FIG. **2**B is a simplified diagram of a sampling-while-drilling logging device **1150** (LWD tool **1150**), and may be used to implement the LWD module **1036** of FIG. **2**A. A probe **1152** may extend from a stabilizer blade **1158** of the LWD tool **1150** to engage a bore wall **1160** that may in some cases be lined by a mud cake **1153**. The stabilizer blade **1158** includes one or more blades that engage the bore wall **1160**. The LWD tool **1150** may be provided with a plurality of backup pistons **1162** to assist in applying a force to push and/or move the LWD tool **1150** and/or the probe **1152** against the bore wall **1160**.

The probe **1152** is configured to selectively seal off or isolate selected portions of the wall of the wellbore **1160** to fluidly couple to the adjacent formation **10** and draw fluid samples from the formation **10** into the LWD tool **1150** in a direction generally indicated by arrows **1156**, for example by using a syringe pump **1175** (for example similar to the pump **1121** of FIG. **1**). Once the probe **1152** fluidly couple to the adjacent formation **10**, various measurements may be conducted on the sample such as, for example, a pretest parameter or a pressure parameter may be measured.

In the illustrated example, a downhole control system **1180** is configured to control the operations of the LWD module **1150** to draw fluid samples from the formation **10** and in particular to control the syringe pump **1175** during sampling operations. Further, the downhole control system **1180** may have capabilities for processing, and storing information collected by downhole sensors (not shown), in particular for subsequent retrieval at the surface and/or for real time communication with the surface equipment. Still further, the downhole control system **1180** may be configured to control one or more mobilizer(s) (not shown) used to mobilize the downhole fluid in at least a portion of the formation prior to or during sampling.

FIG. **3** shows a diagram of a modular testing tool **26** lowered in a wellbore **11** penetrating a subterranean formation **10**. The testing tool **26** may be conveyed by wire-line, drill-pipe, or tubing or any other means used in the industry. For the sake of brevity and clarity, only a portion of the components of the tool **26** are depicted in FIG. **3**.

The modular tool **26** comprises preferably, but not necessarily a plurality of modules of similar functionality. In FIG. **3**, a first testing module **20***a* is depicted in a sampling position and a second module **20***b*, comparable to the first module **20***a*, is depicted in a conveyance position. The testing modules **20***a*, **20***b* are each provided with a probe, denoted respectively by **21***a*, **21***b*, and defining a sampling port or inlet of the testing tool. In the extended position, the probe **21***a* is pressed against a wall of the wellbore **11** with setting pistons **24***a*. When set, the probe **21***a* sealingly engages a wall of the wellbore **11**, establishing thereby an exclusive fluid communication between the flow-line **28***a* and the formation **10**.

For sampling some reservoirs, such as heavy oil or bitumen reservoirs, the tool **26** may be provided with means for mobilizing of the hydrocarbon in the formation **10**. In one example, the probe **21***a* is provided with heating pads **25***a* (e.g. a resistive heating element) that are applied against the formation as the probe **21***a* is extended. The heating pads **25***a* generate heat that is conducted in a portion of the formation close to the probe. The conducted heat elevates the temperature of the hydrocarbon within the formation, thereby reducing its viscosity. In another example, the probe **21***a* is provided with electro-magnetic transducers for propagating an electro-magnetic field in a portion of the formation. Consequently, the electro-magnetic field may generate an inductive or galvanic current in the portion of the formation. Because of the resistance of the formation, the current may be converted into heat in the portion of the formation. Accordingly, the temperature of the hydrocarbon may increase, thereby reducing its viscosity. The electro-magnetic field may have frequency components ranging from DC to several GHz.

While electrical heat sources have been discussed with respect FIG. **3**, other heat sources may alternatively be used, such as chemical heat sources, for example as disclosed in U.S. Pat. App. Pub. No. 2008/0066904, incorporated herein by reference. Further, while particular methods of heat delivery to the formation have been discussed with respect to FIG. **3**, other delivery methods, including perforating the formation, may also be used, for example as disclosed in U.S. Pat. App. Pub. No. 2008/0078581, incorporated herein by reference. Still further, while increasing the temperature of the formation near the probe has been discussed with respect to FIG. **3**, plausible means for mobilizing the heavy oil and bitumen to permit sampling also include injecting a diluent. However, the use of a solvent may result in the precipitation of asphaltenes in the formation and the acquisition of an unrepresentative sample.

To draw fluid from the formation, and in particular a portion of the hydrocarbon that has been mobilized with the heat pads **25***a*, the testing tool **26** is provided with one or more syringe pump(s) fluidly connected to the flow line **28***a*. In FIG. **3**, two syringe pumps are implemented with vessels **30***a* and **30***b*, each of which includes a piston slidably disposed therein. The piston defines a first volume configured to receive formation fluid from the probe inlet and a second volume fluidly isolated from the first volume. The flow of fluid in the flow-line **28***a* to and/or from the vessels **30***a* and **30***b* is controlled by valves **35***a* and **35***b*, respectively. In particular, valves **35***a* and **35***b* may be selectively opened for receiving formation fluid therein. Also, valves **35***a* and **35***b* may be closed once a fluid has been collected in the vessels **30***a*, and **30***b* respectively. By closing the valves **35***a* and **35***b*, the sample collected in the vessels **30***a*, and **30***b* respectively may be isolated from the flow-line **28***a* for transporting the sample to the surface.

To control the movement of the piston in the vessels **30***a* and **30***b*, the testing tool **26** is provided with a hydraulic line

40, that is connected to a pump (not shown). The hydraulic line **40** is preferably provided with a pressure sensor **41** for monitoring and controlling the pressure of the hydraulic fluid therein. The hydraulic line **40** is connected to the second volume of each of the vessels **30***a* and **30***b* through valves **32***a* and **32***b* respectively. To draw formation fluid in the vessel **30***a*, the pressure in the flow line **40** is, for example, lowered at least below the formation pressure, and in some cases with a minimal decrease in pressure with respect to the formation pressure. The valve **32***a*, e.g. a needle valve, is opened for controlling the flow-rate of hydraulic fluid leaving the vessel **30***a*, and consequently, the movement of the piston disposed in the vessel **30***a*. Fluid, for example mobilized fluid, may thus be extracted from the formation and enter the vessel **30***a*. Controlling at least one of the pressure and the flow rate in the flow line **40** as fluid enters a vessel may insure that the received sample is representative of the formation substance, so that the sample can be used to determine the chemical and physical properties to assist, for example, with the definition of a suitable production strategy. In addition, controlling the pressure of the captured sample may insure that the samples remain representative of the formation substance during transportation of the sample to the surface.

In some cases, the sampled hydrocarbon (e.g. the sampled heavy oil) may be such that the fluid extracted from the formation does not readily flow through the hydraulic components of the testing tool **26**. The hydrocarbon could, for example, create a blockage within the flow-line between the sampling probe and the storage vessel (e.g. flow-line **28***a*). In these cases, the testing tool may be advantageously provided with probe and/or flow line heating means (not shown), for example as disclosed in G.B. Pat App. No 2,431,673, incorporated herein by reference.

To measure physiochemical properties of the fluid extracted from the formation, vessels **30***a* and **30***b* may be provided with instruments **36***a* and **36***b*, respectively. The instrument **36***a* and/or **36***b* are configured to measure one or more of a fluid composition, a density, a viscosity, a thermal conductivity, a heat capacity and a complex electric permittivity of the sample received in the vessel. The instrument **36***a* and/or **36***b* may alternatively be disposed on the flow-line **28***a*; however in this alternative, the volume between the inlet of the sampling probe and the vessel may be larger than in the case the instrument **36***a* and/or **36***b* is disposed in the vessel **30***a* and/or **30***b*.

It should be appreciated that the testing tool **26** is preferably capable of capturing in the storage vessels an aliquot of formation hydrocarbon having a composition that represents the important characteristics of the reservoir characteristics sufficiently well. A sufficient volume of formation hydrocarbon should be captured in the vessels, so that Pressure-Volume-Temperature (PVT) analyses at surface in a laboratory may be performed. The minimal volume of formation hydrocarbon that may be required to provide representative physicochemical properties values in a laboratory is on the order of 10 cm^3. In many hydrocarbon reservoirs, the fluid extracted from the formation also contains formation water together with hydrocarbons, in proportion of up to 50% of the extracted fluid volume. Therefore, the minimal volume of pristine formation fluid that the vessels **30***a* and **30***b* should hold may be on the order of 20 cm^3. Larger volumes of pristine formation fluid may be captured in the vessels **30***a* and **30***b*, but it should be appreciated that when heating is used to mobilize the formation, the time required for sampling is increased when larger volumes are acquired.

Usually, samples acquired by formation testers contain drilling fluid filtrate, with or without solid suspension (mostly sand), in addition to pristine formation fluid. In the case of, heavy oil or bitumen reservoirs, and generally reservoirs where the formation fluid has a viscosity value in excess of approximately 100 cP, the reservoir fluid has generally three properties that significantly reduce (or even negate) the probability the drilling lubricant will flow in the formation. Indeed, in these viscous hydrocarbon reservoirs, the compressibility of the formation fluid is at least an order of magnitude lower than that of conventional oil, the viscosity of the formation fluid is at least 10 times greater than that of conventional oil, and the Gas-to-Oil Ratio (GOR) is lower than that of conventional oil. If filtrate invasion in the formation is minimal, as suggested above, the fluid collected with the tester tool **26** may have minimal drilling fluid contamination. Thus, the need to remove filtrate from the formation prior to take a sample may be reduced. However, the tool **26** is capable of ejecting a bad sample into the wellbore if desired, for example by retracting the probe and recycling the piston in the vessels **30***a*, **30***b*.

Alternatively, the testing tool **26** may be configured to pump filtrate from the invaded zone from above and below the probe. Such technique is known in the art and is usually referred to as "guard sampling" or "focused sampling". This technique may be advantageous in horizontal wells when the horizontal permeability is larger than the vertical permeability. As shown, the probes **21***a* and **21***b* are provided with a guard inlet selectively coupled to a guard flow-line **42** via a valve **35***c*. The guard flow line is coupled to a pump (not shown). The pump is used to extract unwanted mud filtrate before and/or during filling the sample vessels **30***a* or **30***b*. A sensor **36***c* may be provided for distinguishing between mud filtrate and formation fluid flowing in the flow-line **42**. When formation fluid is detected, one of the vessel **30***a* or **30***b* may be used to capture a mobilized formation fluid sample.

In yet another alternative (not shown), the testing tool **26** may be configured to implement sampling using a technique sometimes referred to as "reverse low shock". This technique may also provide a low flow line volume between the sampling probe and the sample vessel. For example, a sample vessel is provided between a sampling probe and a pump. The sample vessel may be selectively bypassed using a bypass flow line and suitable valve configuration. Optionally, the samples may be pressurized above formation pressure by reversing the pump direction.

FIG. **4**A shows a diagram of a testing tool **126** lowered in a wellbore **11** penetrating a formation **10**. The testing tool **126** could be conveyed by wire-line, drill-pipe, or tubing or any other means used in the industry. For the sake of brevity and clarity, only a portion of the components of the tool **126** are depicted in FIG. **4**A.

In FIG. **4**A, a testing tool **126** is depicted in a sampling position. The testing tool **126** is provided with a probe **121** similar to the probe **1116** and/or **1152** of FIGS. **1** and **2**B respectively. The probe **121** may be provided with means for mobilizing the hydrocarbon in the formation **10** , for example similar to means for mobilizing of the hydrocarbon in the formation **10** discussed in the description of FIG. **3**. The probe **121** defines a sampling port or inlet of the testing tool **126**, through which fluid may enter the tool. In the extended position, the probe **121** is pressed against a wall of the wellbore **11** with setting pistons **124**. When set, the probe **121** sealingly engages a wall of the wellbore **11**, establishing thereby an exclusive fluid communication between a flow-line **128** and the formation **10**.

The testing tool **126** may be provided with a plurality of sample storage vessels, such as vessels **130***a* and **130***b*. The sample storage vessels **130***a* and **130***b* are disposed in chambers **151***a* and **151***b* respectively, of a revolving chambered cylinder **150**. The cylinder **150** is rotatably disposed within the tool **126**. The cylinder **150** is operatively coupled to an actuator **155** (e.g. a motor) for moving the cylinder **150** between a plurality of positions. In each position, an end **129** of the flow-line **128** registers with a neck of a sample storage vessel. As shown in FIG. **4**A, the neck **137***a* of the vessel **130***a* registers with the end **129** of the flow line **128**. By revolving the cylinder **150** by half a turn with the actuator **155**, the neck **137***b* of the vessel **130***b* would register with the end **129** of the flow line **128** (not shown).

To secure the vessels **130***a* and **130***b* in the chambers **151***a* and **151***b* respectively, the cylinder **150** is provided with a notch defined by the protuberances **152***a* and **152***b* and the vessels **130***a*, **130***b* are provided with bosses **132***a* and **132***b* respectively. In FIG. **4**A, the vessel **130***a* is shown in a sampling position in which the neck **137***a* sealingly engages the end **129** of the flow line **128**, and the vessel **130***b* is shown in a storage position in which a boss **132***b* affixed to the vessel **130***b*, latches onto the protuberances **152***b*, thereby securing the vessel **130***b* in the chamber **151***b*. The vessels **130***a* (as shown) and **130***b* (not shown) may be moved between sampling and storage position with the ram **143** as further detailed below.

To seal fluid within the sample vessels **130***a* and **130***b*, the neck **137***a* and **137***b* of the vessels are provided with self-sealing valves **135***a* and **135***b* respectively. In FIG. **4**A, the valve **135***a* is shown in an open position in which a flow aperture **133***a* allows for fluid to flow in or out of the vessel **130***a*, and the valve **135***b* is shown in a closed position in which flow through a flow aperture **133***b* of the vessel **130***b* is prevented. The valves **135***a*, **135***b* are maintained in a normally closed position, for example with a spring (not shown).

To move the vessel **130***a*, **130***b* between storage and sampling positions and/or to slide a piston **131***a*, **131***b*, respectively, within the vessel **130***a*, **130***b* the tool **126** is provided with, for example, a ram **143** in threadable engagement with a lead screw **142**. The lead screw **142** may be rotated in both directions with a motor **140**, preferably via a gear box **141** operatively coupled therebetween. Thus, the ram **143** may be moved up and down. Preferably, the displacement, and/or the force applied by the ram **143** on the piston **131***a* **131***b* are sensed and controlled during operations of the tool **126**, for example using current sensors, and/or position sensors (not shown) coupled to the motor.

In operations, the cylinder **150** may be provided with a plurality of vessels, all disposed in a storage position (as shown with respect to vessel **130***b*). The ram **143** may initially be in a retracted position in which it does not engage with the cylinder **150** (not shown). As a formation of interest is reached by the testing **126**, the probe **121** and the setting pistons may be extended (as shown). The cylinder **150** may be rotated to register one still empty vessel of the plurality of vessels (the vessel **130***a* in FIG. **4**A) with the end **129** of the flow line **128**. Then, the ram **143** may be extended to move the selected vessel (the vessel **130***a* in FIG. **4**A) into a sampling position in which a fluid communication between the flow line **128** and an interior of the vessel is established. Also, as the ram **143** extends, hooks **139***a*, **139***b* affixed to the piston **131***a*, **131***b* respectively, may latch onto a groove **146** of the ram **143**, thereby operatively coupling the piston **131***a* **131***b* to the ram **143**.

Next, formation fluid sampling may begin. If desired, formation fluid in the vicinity of the probe **121** may be mobilized. Then, fluid (mobilized fluid) may be drawn from the formation into the vessel **130***a* by retracting the ram **143**. As mentioned before, the retraction rate should be controlled to insure a representative sample is captured. The piston **131***a* may be moved until it reaches a shoulder **134***a* of the vessel **130***a*. As the ram **143** further retracts, the vessel **130***a*moves back into a storage position, in which the vessel **130***a* is secured within the chamber **151***a*with the boss **132***a* engaged in the notch defined by protuberances **152***a*. Also, as the neck **137***a* disengages from the flow line **128**, the self sealing valve **135***a* returns to its normally closed position, sealing thereby the fluid in the vessel **130***a*. As the ram **143** still further retracts, the hooks **139***a* unlatch from the ram **143**.

FIG. **4**B is a perspective view showing in more details of the revolving chambered cylinder **150** shown in FIG. **4**A, as well as the vessels **130***a*, **130***b* and their respective self-sealing valves **135***a*, **135***b*. As shown in FIG. **4**B, the cylinder **150** may include an array of sample vessels (e.g. more than two vessels) that can rotate about a pivot located about the axis of symmetry.

While the vessels in FIGS. **4**A and **4**B serve as syringe pump, the tool **126** may be provided with an additional pump **138** coupled to the flow line **128**. The pump **138** may be used to selectively extract mud filtrate from the formation and dispose it in the wellbore **11**. A sensor **160** may be disposed on the flow line **128** and be used to distinguish between mud filtrate and connate formation fluids. Based on data provided by the sensor **160**, a valve **180** may be actuated to selectively admit connate formation fluid in the vessel **130***a*. In one example, the pump **138** may be implemented using a syringe pump. In this example, formation hydrocarbon may be drawn in the syringe pump and then a selected vessel may be filled by expulsing the formation hydrocarbon from the syringe pump into the selected vessel (see FIG. **5** for example).

FIG. **5** shows a diagram of a testing tool **226** lowered in a wellbore **11** penetrating a formation **10**. The testing tool **226** could be conveyed by wire-line, drill-pipe, or tubing or any other means used in the industry. For the sake of brevity and clarity, only a portion of the components of the tool **226** are depicted in FIG. **5**.

The testing tool **226** is provided with a probe **221** similar to the probe **1116** or **1152** of FIG. **1** or **2**B, respectively. The probe **221** may be provided with means **225** for mobilizing of the hydrocarbon in the formation, for example similar to the means for mobilizing of the hydrocarbon in the formation **25***a* discussed in the description of FIG. **3**. The probe **221** defines a sampling port or inlet of the testing tool **226**, through which fluid may enter the tool. In the extended position, the probe **221** is pressed against a wall of the wellbore **11**. When set, the probe **221** sealingly engages a wall of the wellbore **11**, establishing thereby an exclusive fluid communication between a flow-line **256** and the formation **10**.

A syringe pump **280** is provided for flowing fluid in the testing tool **226**. In the shown example, the syringe pump **280** is in selective fluid communication with the flow line **256** through a valve **281**. In a fist position (not shown) of the valve **281***a*, fluid is extracted from the formation as a drawdown piston included in the pump **280** is retracted. In a second position of the valve **281***a*, fluid received in the pump **280** may be expulsed from the pump towards an end **257** of the flow line **256** as the drawdown piston included in the pump **280** is extended. The end **257** of the flow line **256** may be in fluid communication with one of a plurality of sample storage vessels **230** disposed in a carousel, and configured to store the expulsed fluid from the syringe pump **280**. The carousel may be disposed proximate the probe inlet, so that the volume of the interconnecting flow line is small compared with the volume of mobilized hydrocarbon obtained from the formation. Thus, the majority of mobilized hydrocarbon obtained from the formation may be stored in one of the storage vessels in the carousel. Further, a valve **281***b* may be used to selectively dispose unwanted fluid into the wellbore **11**, for example based on data collected by a flow line sensor (not shown).

The testing tool **226** includes a system for efficiently handling and storing multiple sample storage vessels. Accordingly, the testing tool **226** may include a vessel carousel **220** having at least one of first and second storage columns **222**, **224** each sized to receive vessels **230** adapted to hold fluid samples. In the illustrated embodiment, each storage column **222**, **224** is shown holding four vessels **230**, however, the columns may be sized to hold more or less than four vessels depending on the dimensions of the vessel carousel **220**. The vessel carousel **220** defines a proximal end **228** positioned nearer to the flow line **256** and a distal end **250** positioned farther from the flow line **256**.

Shifters **232**, **234** may be provided to move vessels between the storage columns **222**, **224**. In the illustrated embodiment, the shifter **232** is coupled to the vessel carousel proximal end **228** and includes fingers **216** adapted to grip an exterior of one vessel **230**. The shifter **232** is mounted on a spindle **236** and may rotate from a first position in which the shifter **232** registers with a proximal end of the first storage column **222**, to a second position in which the shifter registers with a proximal end of the second storage column **224**. The other shifter **234** is coupled to the vessel carousel distal end **250** and is similarly rotatable between a first position in which the shifter **234** registers with a distal end of the first storage column **222** and second position in which it registers with a distal end of the second storage column **224**.

A first transporter is provided for transferring an empty vessel from the first storage column **222** up to the proximal shifter **232** and into sealing engagement with the flow line **256** as it moves from the retracted position to an extended position. In the illustrated embodiment, the first transporter comprises a lift piston **240**, such as a ball screw piston, which is positioned coaxially with respect to the receptacle first storage column **222** and is further coaxial with an end **257** of the flow line **256**. In its extended position, the lift piston **240** also passes through the distal shifter **234** and is configured to advance a vessel **230** from the distal shifter **234** to the first storage column **222**.

A second transporter, such as push down piston **260**, may be provided to transfer a filled vessel **230** from the proximal shifter **232** to the second storage column **224**. As shown in FIG. **5**, the push down piston **260** is coaxial with the second storage column **224** and adapted to move from a retracted position to an extended position in which it passes through the proximal shifter **232** and partially into the second storage chamber **224**. As it moves to the extended position, the push down piston **260** will transport a vessel disposed inside the proximate shifter **232** into the second storage column **224**. Also, the push down piston **260** will transport a vessel disposed inside the second storage column **224** into the distal shifter **234**.

Each vessel **230** is provided with an auto-connect and normally closed (or self-closing) valve assembly disposed on a neck thereof. Each vessel may be filled when connected to the end **257** of the flow-line **256** with formation fluid (e.g. mobilized hydrocarbon) that has been drawn previously in the syringe pump **280**. Further, each vessel **230** is preferably provided with a spring **210**, or other compliant material, that is compressed as the neck of vessel **230** is engaged into the end **257** of the flow line **256**. The spring may then provide a force for disengaging the neck of the vessel from the end **257** of the flow line **256**. The spring may also assist load transmission between vessels in the storage columns while protecting the connecting mechanism thereof. Still further, the vessels may include a sliding piston (not shown) having one face in fluid communication with fluid (e.g. wellbore fluid, hydraulic oil) that may be present in at least one storage column **222** or **224** as the other face is in fluid communication with the fluid sample flowing through the inlet of the probe **221**.

In operation, the handling assembly may be used to transfer vessel between the carousel **220** and the end **257** of the flowline **256**, and store vessels in multiple adjacent storage columns. Prior to lowering the tool **226** in the wellbore **11**, the first and second storage columns **222**, **224** of the carousel **220** may be filled with empty vessels. The vessels may be of any type capable of receiving and storing fluid samples. These would include a first vessel **230***a* positioned at a proximal end of the first storage column **222** and a second vessel **230***b* positioned at a distal end of the first storage column **222**. In addition, a third vessel **230***c* is positioned at a distal end of the second storage column **224** and a fourth vessel **230***d* is positioned at a proximal end of the second storage column **224**.

The sampling probe **221** and the syringe pump **280** may be operated to obtain formation fluid in the syringe pump **280**. The lift piston **240** may then be extended so that the vessel **230***a* is ejected from the first storage column **222**. The proximal shifter **232** may be positioned to register with the first storage column, thereby to receive the ejected vessel **230***a*. Further extension of the lift piston **240** sealingly engages the vessel **230***a* into the end **257** of the flow line **256** and compresses the spring **210**. The valve **281** may then be activated to fluidly connect the pump **280** to the vessel **230***a*, and the fluid captured in the pump may be transported into the vessel **230***a*. Partial retraction of the lift piston **240** permits the spring **210** to extend and to disengage the vessel **230***a* from the flow line **256**. The distal shifter **234** may then rotate to register with the first storage column **222**, thereby transferring the vessel **230***c* to be positioned adjacent the distal end of the first storage column **222**. By this time, the lift piston **240** may be at least partially retracted so that it is clear of the distal shifter **234**.

Next, the push down piston may be retracted so that it is clear of the proximal shifter **232**. The proximal shifter **232** may then be rotated to register with the second storage column **224** and the push down piston **260** may be extended to insert the vessel **230***a* into the second storage column proximal end. As the vessel is inserted into the second storage column **224**, the entire second series of stacked vessels is advanced in a distal direction along the second storage column **224** thereby ejecting a vessel from the distal end of the second storage column **224**. The distal shifter **234** may be positioned to register with the second storage column **224**, thereby to receive the ejected vessel. The above steps may then be repeated until each vessel contains a sample.

FIG. **6** shows a detailed diagram of means for mobilizing fluid in the formation that can be used the testing tools of the present disclosure. The testing tool **900** also includes an injection pump **918** coupled to an injection port **902**. In operation, with the example configuration **900** of FIG. **6**, as the electrodes **906-912** heat the subterranean formation **10**, the injection pump **918** may apply a pressure to a displacement fluid **920** (e.g. a solvent, a diluents), which applies pressure to the fluid within the subterranean formation **10**.

The testing tool **900** is provided with a plurality of electrodes **906**, **908**, **910**, and **912** that are arranged between the injection port **902** and the sampling port **904** to heat a volume of the formation **10** proximate to the sampling port **904**. One or more electrical power sources (**940**, **941**) may be coupled to the electrodes **906-912** to flow current in the formation along, for example, lines or paths **914**. Because of the resistance of the formation, the current may be dissipated into heat in the portion of the formation. Accordingly, the temperature of the hydrocarbon in the volume located between the injection port and the sampling port may increase, thereby reducing its viscosity. The power source field may operate at frequencies from DC to several GHz.

A pressure sensor (not shown) may monitor the pressure applied by the displacement fluid **920** on the fluid in the subterranean formation **10**. As the fluid within the heated portions of the subterranean formation **10** becomes increasingly mobile, the pressure on the displacement fluid **920** decreases. The drop in pressure may be compensated by increasing or decreasing the amount of force applied to displacement fluid **920** by the injection pump **918**. The pressure from the displacement fluid **920** causes a sample of the mobile fluid in the heated portion of the subterranean formation **10** to flow into the sampling port **904**.

Extending on both sides of the ports **902** and **904** there is a packer **922**, which is deployed against the wellbore wall in the circumferential direction to seal a substantial portion of a perimeter of the wellbore **11**. As the injection pump **918** exerts pressure on the displacement fluid **920**, the displacement fluid **920** is pushed into the subterranean formation **10** and exerts pressure in every direction. Hydraulic shorting may occur between the injection port **902** and the wellbore **11**. Also, the heated formation fluid may flow into the wellbore **11** instead of the production port **904**. The packer **922** seals the wellbore, and prevents hydraulic shorting between the wellbore **11** and the formation **10**.

The syringe pump **916** may assist the flow of the fluid sample by drawing in the fluid sample. The syringe pump **916** is used to reduce the parasitic volume of fluid associated with the testing tool **900**. Such a reduction of the parasitic volume of fluid enables a relative reduction in the amount of formation to be heated and, thus, time needed to collect a given fluid sample volume. It should be noted that when solvent injection is used, adaptations of the sample collection vessel volume may be required to acquire a sufficient volume of hydrocarbon from the formation, owing to the volume occupied by the solvent present in the formation fluid. Modifications of the testing tool may also be required to accommodate instrument to identify and quantify the presence of solvent that may have contaminated the hydrocarbon sample. These instruments may include components of the existing Optical Fluid Analyzer that measure fluid color amongst other optical properties, or other sensors that measure of fluid resistivity.

FIGS. **7**A and **7**B show a portion of another formation tester **300** according to one or more aspect of this disclosure. The formation tester **300** shown in FIGS. **7**A and **7**B may be referred to as a "single packer" formation tester. It should be understood that FIGS. **7**A and **7**B omit a number of elements for clarity of the illustration that are well known to those skilled in the art. Thus, the exact configuration of the formation tester **300** shown in FIGS. **7**A and **7**B may be the same or different than as shown, the figures being only one example of a single packer formation tester configuration.

Similarly to the testing tool **900** of FIG. **6**, the formation tester **900** is provided with an outer sealing layer **306**, such as can be made from an elastomer such as a fluorocarbon polymer, that is configured to sealingly engage a substantial portion of a perimeter of a wellbore wall (not shown). The sealing layer **306** can be made to contact the wellbore wall to create a seal, for example by inflation via an inflation port **382** of a sleeve **380** disposed around a mandrel **302** of the formation tester **300**.

The sealing layer **306** is traversed by a plurality of C shaped flow lines, for example, **320**, **330** and **335**. The flow lines are rotatably affixed between fluid collectors **310** and **312**. Upon inflation of the sleeve **380**, the flow lines **320**, **330** and **335** may pivot in the collectors **310** and **312** and a middle portion of the flow lines may extend in a general radial direction away from the mandrel **302**. Conversely, upon deflation of the sleeve **380**, the flow lines **320**, **330** and **335** may pivot in the collectors **310** and **312** and a middle portion of the flow lines may retract in a general radial direction towards the mandrel **302**. In the example of FIGS. **7**A and **7**B, the flow line **320** is fluidly coupled to a first pump **360** (e.g. a progressive cavity pump) via the fluid collector **312**, and the flow lines **330** and **335** are fluidly coupled to a second pump **361** (e.g. a progressive cavity pump) via the fluid collector **310**. While three flow lines connected to two pumps are described herein, the formation tester **300** may include less or more flow lines, connected to one or more pumps.

A first plurality of openings or ports **332**, **333**, **337**, and **339** may be disposed at selected positions through the sealing layer **306**. In the example of FIGS. **7**A and **7**B the ports **332** and **333** are hydraulically connected the flow line **330**, and the ports **337** and **339** are hydraulically connected a flow line **335**. At least one inlet or port **322** may further be disposed at a selected position through the sealing layer **306**. In the example of FIGS. **7**A and **7**B the port **322** is hydraulically connected the flow line **320**. In an extended position of the sealing layer **306**, the ports **332**, **333**, and **337** establish a fluid communication between the formation and one of the flow lines **320**, **330** or **335**. For example, the ports **332**, **333**, and **337** may be used to inject a displacement fluid (e.g. wellbore fluid) into the formation upon actuation of the pump **361**, similarly to the formation tester of FIG. **6**. Alternatively, the ports **332**, **333**, and **337** may be used to draw fluid (e.g. mud filtrate) from the formation. Also, the port **322** may be used to draw formation fluid into the formation tester **300** upon actuation of the pump **360**. While five ports connected to two pumps are described herein, the formation tester **300** may include less or more ports, connected to one or more pumps.

A plurality of heat sources, for example **340**, **342** may be evenly or otherwise spatially distributed in the sealing layer **306** near the outer surface of the sealing layer **306**. For example, the heat sources **340**, **342** may be configured to emit electromagnetic energy into the formation at a frequency selected to heat any residual water within the pore space of the formation. Because the heat sources **340**, **342** are spatially distributed in the sealing layer **306**, by appropriate selection of particular ones of the heat sources **340**, **342** to be actuated, the efficiency of the propagation of heat through the formation can be maximized. Optionally, the flow lines **320**, **330** and **335** may also be heated, for example, by electric resistance heating elements (not shown) to maintain movement of fluid from the formation by reducing the amount of cooling-associated increase in viscosity.

As mentioned before, one or more ports **322** disposed through the sealing layer **306** may be used to withdraw samples of formation fluid for capture. In this case, the port **322** may be in hydraulic communication with a sample chamber implemented in the flow line **320**. The flow line **320** may comprise a piston **352**, optionally disposed in an enlarged portion of the flow line **320**. As shown in FIG. **7**B, the piston **352** fluidly isolates a fluid flow path between the port **322** and the pump **360**. The flow line may further comprise a valve **350** configured to seal a sample in the flow line **320**. A portion of the flow line **320** may thus be used as a vessel to admit and capture a formation fluid. Once the sampling operation is completed, the flow line **320** (together with the sealing layer **306**) may be detached from the formation tester at the surface, placed in a pressure safe container, and transported to a laboratory. Alternatively, the captured fluid can be drained at the wellsite.

Optionally, the flow line **320** may include additional valves (not shown) disposed between the piston **352** and pump **360** and configured to be closed to further secure the sample of formation fluid captured in the sample chamber implemented in the flow line **320**. For example, the additional valves may be disposed in the collector **312**.

FIG. **7**C shows another configuration **300'** of the formation tester shown in FIG. **7**A. In this configuration, the flow line **320** extending from the inlet **322** is provided with a first valve **353** defining a first volume extending between the inlet **322** and the valve **353**, and a second volume extending between the pump **360** and the valve **353**. After formation fluid is mobilized, the pump **360** may be used to extract fluid from the formation. When a formation sample is received in the first volume, the valves **350** and **353** may be closed, thereby capturing the formation sample between the valves. This configuration may be useful for removing some contaminated fluid from the formation through the flow line **320** before a representative sample is captured. In other words, valves **350** and **353** would remain open during pumping until such time that it has been determined to capture a sample of formation fluid whereupon valves **353** and **350** would be closed to secure a sample of the desired fluid.

In view of all of the above and FIGS. **1** to **7**, it should be readily apparent to those skilled in the art that the present disclosure provides a downhole tool, for use in a borehole formed in a subterranean formation, and comprising a formation fluid mobilizer configured to mobilize a formation fluid; a vessel comprising a piston slidably disposed therein and defining first and second volumes, wherein the first volume is configured to receive at least a portion of the mobilized formation fluid from an inlet port; and an actuator operatively coupled to the piston, the actuator being fluidly isolated from a fluid flow path extending between the inlet port and the first volume. The downhole tool may further comprise a valve configured to control the flow of the formation fluid to the vessel. The formation fluid mobilizer may comprise a heat source. The heat source may comprise an electromagnetic transducer. The actuator may comprise a pumping mechanism configured to at least one of lower a hydraulic oil pressure in the second volume, and extract hydraulic oil out of the second volume. The actuator may comprise a ram configured to reciprocate the piston. The downhole tool may further comprise a plurality of vessels; and a plurality of inlet ports, wherein first and second vessels from the plurality of the vessels are fluidly connected respectively to first and second inlet ports from the plurality of inlet ports. At least one of the plurality of inlet ports may be disposed on a probe configured to selectively extend from the downhole tool. At least one of the plurality of inlet ports may be disposed on a packer configured to deploy against a substantial portion of a perimeter of the borehole. At least one of the vessels may be disposed in the packer. The downhole tool may further comprise a plurality of vessels; a flow-line configured to transfer the formation fluid to at least one vessel from the plurality of vessels; and an actuator configured to register an end of the flow-line with an inlet of the at least one vessel. The at least one vessel may be a first vessel, the plurality of vessels may comprise a second vessel, and the actuator may be configured to register the end of the flow-line with inlets of the first and second vessels respectively in first and second positions. The downhole tool may further comprise a storage column configured to secure the at least one vessel, and the actuator may be configured to register the end of the flow-line with an inlet of the at least one vessel in a first position and to register the at least one vessel with an opening of the storage column in a second position. The downhole tool may be configured to be lowered in the borehole using one of a wireline cable, a tubing, and a drill string.

The present disclosure also provides a method for obtaining a sample of formation fluid. The method includes lowering a downhole tool in a borehole formed in a subterranean formation, the downhole tool comprising a vessel comprising a piston slidably disposed therein and defining first and second volumes; and an actuator operatively coupled to the piston, the actuator being fluidly isolated from a fluid flow path extending between an inlet port and the first volume. The method further includes mobilizing a formation fluid in the formation; operating the actuator to slide the piston in the vessel; and receiving in the first volume at least a portion of the mobilized formation fluid from the inlet port.

The present disclosure also provides a downhole tool, for use in a borehole formed in a subterranean formation, and comprising an inlet port configured to admit a formation fluid in the downhole tool; a vessel configured to receive the formation fluid, the vessel having a valve configured to selectively close an inlet of the vessel; a flow-line configured to deliver the formation fluid from the inlet port to the vessel; and an actuator configured to register an end of the flow-line with the inlet of the vessel. The valve may be a self-closing valve. The downhole tool may further comprise a plurality of vessels; and a revolving chambered cylinder configured to secure at least one vessel from the plurality of vessels and, wherein the actuator of operatively coupled to the revolving chambered cylinder. The downhole tool may further comprise a plurality of vessels; and a storage column configured to secure at least one vessel from the plurality of vessels and, wherein the actuator comprises a shifter configured to register an end of the flow-line with the inlet of the at least one vessel in a first position and to register the at least one vessel with an opening of the storage column in a second position. The downhole tool may further comprise a heat source configured to increase a temperature of a formation fluid.

The present disclosure also provides a method for obtaining a sample of formation fluid. The method includes lowering a downhole tool in a borehole formed in a subterranean formation, the downhole tool comprising a flow-line extending from an inlet pot, a first valve disposed on the flow line and defining first and second volumes, a pumping mechanism operatively coupled to the second volume, and a second valve configured to capture the formation fluid in the first volume. The method further includes mobilizing a formation fluid in the formation, operating the pumping mechanism to flow fluid in the flow-line, receiving in the first volume at least a portion of the mobilized formation fluid from the inlet port, and actuating the first and second valves to capture the formation fluid in the first volume.

The foregoing outlines features of several embodiments so that those skilled in the art may better understand the aspects of the present disclosure. Those skilled in the art should appreciate that they may readily use the present disclosure as a basis for designing or modifying other processes and structures for carrying out the same purposes and/or achieving the same advantages of the embodiments introduced herein. Those skilled in the art should also realize that such equivalent constructions do not depart from the spirit and scope of the present disclosure, and that they may make various changes, substitutions and alterations herein without departing from the spirit and scope of the present disclosure.

What is claimed is:

1. A downhole tool for use in a borehole comprising:

a sampling port for receiving formation fluid from a formation about a borehole;

a flow line in fluid communication with the sampling port for transporting the formation fluid within the downhole tool;

a sample storage vessel in fluid communication with the sampling port, the sample storage vessel having a self-sealing valve;

a ram in contact with the sample storage vessel to move the sample storage vessel into a sampling position in contact with the flow line to open the self-sealing valve and establishing fluid communication with an interior of the sample storage vessel, and further wherein retracting the ram moves the sample storage vessel into a storage position that is not in fluid communication with the flow line, and further wherein the self-sealing valve automatically closes upon moving to the storage position.

2. The downhole tool of claim 1 further comprising a piston within the sample storage vessel, wherein the ram contacts the piston to move the sample storage vessel between the storage position and the sampling position.

3. The downhole tool of claim 2 further comprising hooks affixed to the piston to latch onto the ram thereby operatively coupling the piston to the ram.

4. The downhole tool of claim 1 wherein retracting the ram between the sampling position and the storage position permits the sample storage vessel to be filled with the formation fluid.

5. The downhole tool of claim 1 further comprising a first chamber in a revolving chambered cylinder for disposing the sample storage vessel.

6. The downhole tool of claim 5 wherein the revolving chambered cylinder has a second chamber for storage of another sampling storage vessel, and further wherein the cylinder is rotably disposed within the tool.

7. The downhole tool of claim 6 wherein the first chamber has a protuberance and further wherein the sampling storage vessel has a boss latching into the protuberance.

8. The downhole tool of claim 1 further comprising a formation fluid mobilizer configured to mobilize a formation fluid by reducing viscosity of the formation fluid.

9. The downhole tool of claim 8 wherein the formation fluid mobilizer comprises a heat source.

10. The downhole tool of claim 1 wherein the sampling port is disposed on a packer configured to deploy against a substantial portion of a perimeter of the borehole.

11. The downhole tool of claim 10 wherein the sampling storage vessel is disposed in the packer.

12. A method for sampling a formation fluid in a borehole comprising:

lowering a downhole tool in the borehole formation in a subterranean formation, the downhole tool having a revolving chambered cylinder storing a plurality of sample storage vessels therein, and the downhole tool having a piston within each of the plurality of sample storage vessels and movable within each sample storage vessel;

sampling formation fluid about the borehole;

drawing the formation fluid into the downhole tool through a flow line within the downhole tool and into a first one of the sample storage vessels rotating the revolving chambered cylinder to draw formation fluid into a second one of the sample storage vessels; and

providing a ram in contact with one of the sample storage vessels to move the one of the sample storage vessels into a sampleing position in contact with the flow line and further wherein retracting the ram moves the one of the sample storage vessels into a storage position that is not in fluid communication with the flow line.

13. The method of claim 12 further comprising moving the first sample storage vessel from a storage position within a chamber in the revolving cylinder to a sampling position in fluid communication with the flow line.

14. The method of claim 13 wherein moving the first sample storage vessel from the storage position to the sampling position comprises extending a ram in contact with the first sample storage vessel to move the first sample storage vessel into contact with the flow line to at least partially fill the first sample storage vessel.

15. The method of claim 13 wherein the first sample storage vessel has a self-sealing valve automatically closing in the storage position.

16. The method of claim 12 further comprising decreasing the viscosity of the formation fluid.

17. The method of claim 12 wherein the step of sampling formation fluid about the borehole utilizes a packer having a sampling port.

18. A downhole tool for use in a borehole comprising:

a sampling port for receiving formation fluid from a formation about a borehole;

a plurality of sample storage vessels rotatable within the downhole tool; and

a ram for moving a first sample storage vessel from a storage position to a sampling position, the sampling port being in fluid communication with the first sample storage vessel at the sampling position; and

further wherein retracting the ram moves the first sample storage vessel into the storage position that is not in fluid communication with the flow line.

19. The downhole tool of claim 18 further comprising a flow aperture providing fluid communication to an interior of the first sample storage vessel and a self-sealing valve at the aperture.

20. The downhole tool of claim 18 further comprising a fluid mobilizer for reducing the viscosity of the formation fluid.

21. The downhole tool of claim 18 further comprising a flow line connecting the sampling port to the first sample storage vessel at the sampling position and a sensor disposed on the flow line for distinguishing between mud filtrate and formation fluids.

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